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Prevention of heat illness is an important part of Army training and doctrine. Heat illness has historically been a substantial problem in military operations and training and continues to affect modern forces, increasing morbidity, mortality, and use of health care resources. If adequate hydration and emergency medical management are not available, many cases of exertional heat illness (EHI) are potentially fatal. Therefore the US military is attempting to minimize the risks to Warfighters through predictive modeling and mission planning. Environmental conditions, clothing worn, and activity level can contribute to excess heat storage making it difficult to maintain thermal balance with the environment.
This imbalance can eventually lead to the development of heat illness ranging from relatively minor heat exhaustion to life threatening heat stroke. In addition to weather, clothing, and exertion, increased body mass index (BMI) has recently been shown to increase the likelihood of developing exertional heat illness. USARIEM has developed several models to predict Warfighter performance and requirements. One of these models was retrospectively tested on a database of Marine Corp Recruits to determine how sensitive predictions of exercise endurance time are to individual anthropometric differences.

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EFFECT OF INDIVIDUAL VARIABILITY IN BODY SIZE ON EMPIRICAL MODEL PREDICTIONS OF EXERCISE ENDURANCE TIMES

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Introduction

Prevention of heat illness is an important part of Army training and doctrine. Heat illness has historically been a substantial problem in military operations and training and continues to affect modern forces, increasing morbidity, mortality, and use of health care resources.[1-4] If adequate hydration and emergency medical management are not available, many cases of exertional heat illness (EHI) are potentially fatal.[2,5-8] Therefore the US military is attempting to minimize the risks to Warfighters through predictive modeling and mission planning. Environmental conditions, clothing worn, and activity level can contribute to excess heat storage making it difficult to maintain thermal balance with the environment. This imbalance can eventually lead to the development of heat illness ranging from relatively minor heat exhaustion to life threatening heat stroke. In addition to weather, clothing, and exertion, increased body mass index (BMI) has recently been shown to increase the likelihood of developing exertional heat illness.[9-11] USARIEM has developed several models to predict Warfighter performance and requirements. One of these models was retrospectively tested on a database of Marine Corp Recruits to determine how sensitive predictions of exercise endurance time are to individual anthropometric differences.

Methods

The model chosen for the simulations is an empirically derived model (EM) with documented performance for Warfighter populations working in the heat.[12-17] USARIEM has compiled a database of test results from more than 30 years of experiments. From these, a set of predictive equations was developed for soldiers performing physical work in various clothing configurations under a range of environmental conditions. These algorithms are periodically modified as new data are acquired.

All EHI cases occurring among 217,000 male and female Marine Corps recruits entering 12-week basic training at Marine Corps Recruit Depot, Parris Island, SC from 1988-1992 were collected from medical records.[11] The dataset for the simulation was limited to 2453 Marine Corps recruits (669 cases of EHI and 1723 controls matched by training platoon) for whom weather and anthropometric data were available. Both heat acclimatization[18] and lower BMI [9-11] have been shown to improve heat tolerance. Since Marine Corps recruits generally increase their physical fitness and decrease BMI throughout this demanding training and since the heat acclimation status of arriving Marine Corps recruits was unknown, the dataset was further constrained to weeks 2-5 of training in order to ensure Marine Corps recruits were fully heat-acclimatized and to decrease the likelihood of large changes in BMI compared with later weeks of training. This reduced the number of EHI cases to 263 with 702 controls matched by training platoon.

The environment chosen for the simulation was T_{db} = 27°C, RH = 70%, MRT = 77°C, and wind speed = 2.5m/s based on average ambient conditions faced by this population. Clothing input for EM was the desert battle dress uniform (dBDU) with insulation or R_T=0.2 m^2*K/W. Analysis required some assumptions regarding conditions faced by individual Marine Corps recruits which we accounted for in part by matching EHI cases with controls from the same platoon. These matched Marine Corps recruits should have been exposed to similar conditions during training in terms of uniform, activity, and environment.

Results and Discussion

The risk of EHI was found to increase 18% per kg/m^2 BMI (Odds Ratio = 1.18, 95% CI 1.12-1.24) and 4% per kg weight (Odds Ratio = 1.04, 95% CI 1.02-1.05) for this subgroup of Marine Corps recruits. In this population, weight (76.7±13.8 kg) and BMI (25.0±1.9 kg/m^2) of subjects experiencing EHI were both significantly greater than weight and BMI of controls (71.9±12.1 kg, 23.4±3.1 kg/m^2, $P<0.01$) as shown in Table 1.

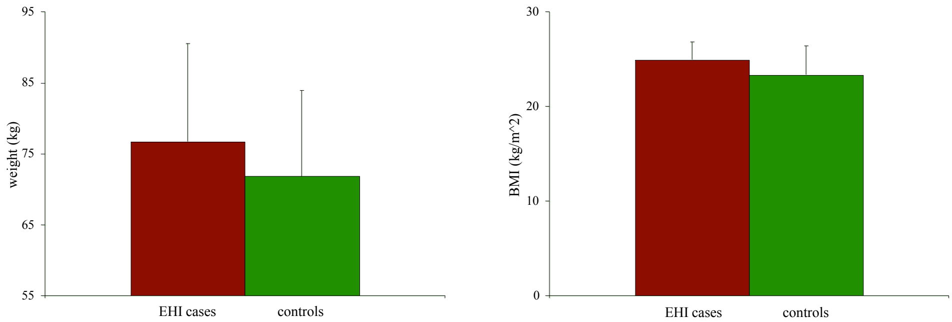
Table 1. Marine Recruit Anthropometry.

	weight range (kg)	mean weight ± std dev (kg)	height range (m)	mean height ± std dev (m)	BMI range (kg/m^2)	mean BMI ± std dev (kg/m^2)
EHI Cases	41.2-119.0	76.7±13.8*	149.9-198.1	174.9±8.2	17.4-32.6	25.0±1.9*
Controls	44.3-109.1	71.9±12.1	149.9-198.1	175.1±8.1	13.1-31.4	23.4±3.1

* t-test p<0.01

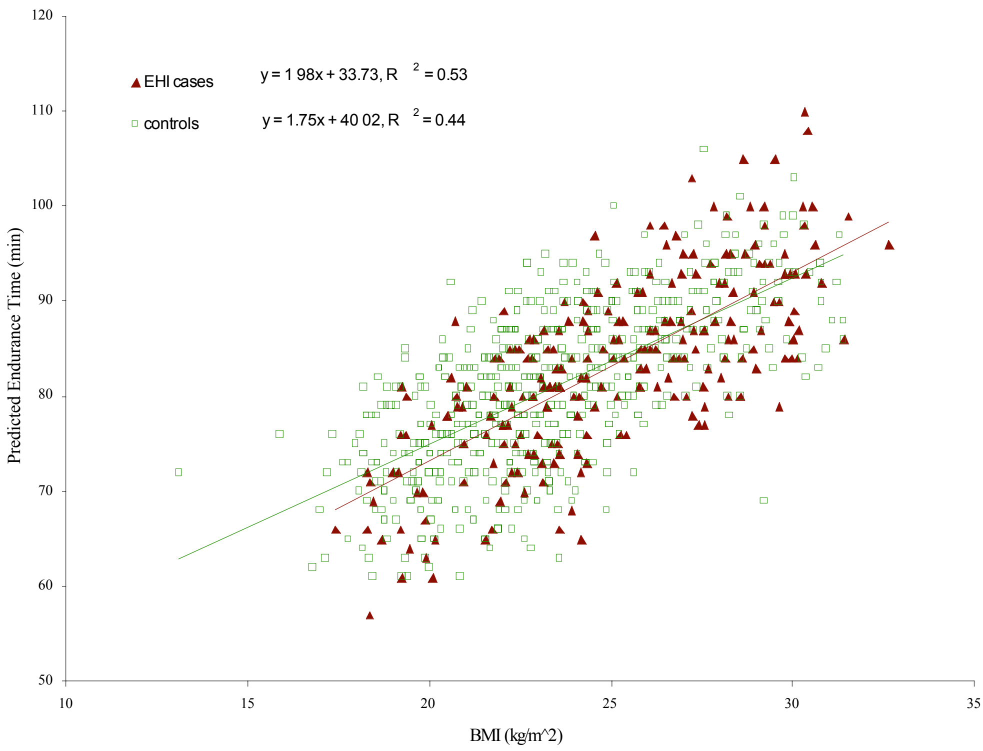
BMI can affect physical performance in various ways. Heat transfer is slower for larger masses with proportionally lower surface areas. Furthermore, a higher BMI could indicate lower fitness; a risk factor of EHI.[9] In this empirical model, height and weight are considered for estimation of heat transfer rate between body and environment but are not factored into adjustments for physical fitness or relative work loads. EM is based primarily on data obtained from experiments on fit young men and does not make allowances for individual variations in physiological response. Comparisons of Marine Corps recruit anthropometry of EHI cases and controls are shown in Figure 1.

Figure 1. Weight and BMI of Marine Corps Recruits



The primary output variable of this model is predicted endurance time. Typically this refers to how many consecutive minutes of exercise could be performed at a given work rate. For this study, we were not looking at responses to one specific exercise bout but instead at how well the Marine Corps recruits fared over the course of several weeks with multiple work episodes of varying difficulty and duration. Figure 2 shows EM predicted endurance times during sustained heavy work (600W) of 83±9 min for the EHI cases and 81±8 minutes for controls (P<0.01).

Figure 2. Predicted Endurance Time vs BMI



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